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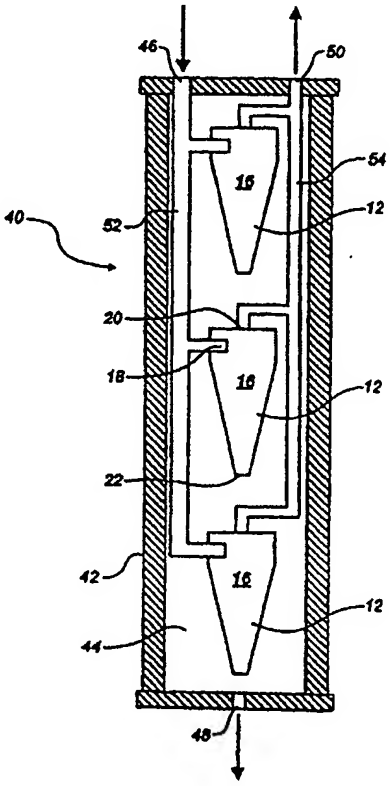
(54) Title: METHOD FOR DOWNHOLE CYCLONE SEPARATION

(57) Abstract

A method of downhole cyclone separation that is less prone to problems associated with gas breakout. This method include the following steps. Firstly, placing a cyclone separator (12) downhole in an oil well (14) producing a mixed stream of oil, water and gas. The cyclone separator (12) includes a separation chamber (16) wherein liquids of differing densities are separated, at least one mixed liquids inlet (18) through which liquids pass into the separation chamber (16), a first outlet (20) for liquids of a first density range to pass from the separation chamber (16), and a second outlet (22) for liquids of a second density range to pass from the separation chamber (16). Secondly, connecting the first outlet (20) to a recovery conduit (24) extending to surface. Thirdly, connecting the second outlet (22) to a disposal conduit (26) extending to a selected disposal site. The method being characterized by the further step of, fourthly, connecting the at least one mixed liquids inlet (18) to a pump (28) and pumping a mixed stream of oil, water and gas into the separation chamber (16) of the cyclone separator (12). The mixed stream is separated into a recovery stream of oil with a reduced water content which flows out of the first outlet (20) and along the recovery conduit (24) to the surface and a disposal stream of mainly water which flows out of the second outlet (22) and along the disposal conduit (26) to the selected disposal site.



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METHOD FOR DOWNHOLE CYCLONE SEPARATION

FIELD OF THE INVENTION

The present invention relates to a method for downhole cyclone separation and, in particular, a method that can be used for oil/water separation in producing oil wells.

BACKGROUND OF THE INVENTION

United States Patent number 5,296,153 teaches a method of reducing the amount of formation water in oil recovered from an oil well through the insertion of a cyclone separator downhole in an oil well producing a stream of mixed oil and water. In accordance with the described method, a first outlet of the cyclone separator is connected to a recovery conduit extending to surface. The recovery conduit conveys a recovery stream of oil with a reduced water content to surface. A second outlet of the cyclone separator is connected to a disposal conduit. The disposal conduit conveys a disposal stream of mainly water to a disposal site, which is usually a

downhole formation chosen to be a disposal zone. The reference goes on to describe various pumping configurations which, when used in combination with the cyclone separator, can further enhance recovery.

United States Patent 4,822,551 which issued to Pendergast in 1989 and United States Patent 5,154,826 which issued to Pendergast et al in 1992 an apparatus for cyclone separation that utilizes multiple cyclone separators. PCT Application WO 94/13930 filed by Read Process Engineering and published June 23, 1994 describes the use of cyclone separators downhole in producing oil and gas wells.

When the production stream from the oil well has a high gas content, great care must be taken in the selection of the pumping configuration. During downhole processing through the cyclone separator and the pump, "gas breakout" inevitably occurs. Gas breakout involves the release of entrained gases from the liquid being pumped. This gas breakout can adversely affect the efficiency of the pumping configuration and may also impact the operation and efficiency of the cyclone separator.

SUMMARY OF THE INVENTION

What is required is an improved method for downhole cyclone separation that is less prone to problems associated with gas breakout.

According to the present invention there is provided a method of downhole cyclone separation. This method

include the following steps. Firstly, placing a cyclone separator downhole in an oil well producing a mixed stream of oil, water and gas. The cyclone separator includes a separation chamber wherein liquids of differing densities are separated, at least one mixed liquids inlet through which liquids pass into the separation chamber, a first outlet for liquids of a first density range to pass from the separation chamber, and a second outlet for liquids of a second density range to pass from the separation chamber. Secondly, connecting the first outlet to a recovery conduit extending to surface. Thirdly, connecting the second outlet to a disposal conduit extending to a selected disposal site. The method being characterized by the further step of, fourthly, connecting the at least one mixed liquids inlet to pumping means and pumping a mixed stream of oil, water and gas into the separation chamber of the cyclone separator. The mixed stream is separated into a recovery stream of oil with a reduced water content which flows out of the first outlet and along the recovery conduit to the surface and a disposal stream of mainly water which flows out of the second outlet and along the disposal conduit to the selected disposal site.

Gas breakout adversely affecting pumping operation occurs due to pressure drop and agitation as the mixed stream passes through the separation chamber of the cyclone separator. Placing pumping means upstream of the cyclone separator, as described above, is a more effective pumping configuration. The pump, being upstream, is isolated from whatever gas breakout may occur as the mixed stream passes through the separation chamber and is separated into the recovery stream and the disposal stream. Pumping fluids through the separator

reduces gas breakout, as it increases the pressure of fluids within the separator and forces the gas to remain in solution.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other features of the invention will become more apparent from the following description in which reference is made to the appended drawings, wherein:

FIGURE 1 is a schematic diagram of a first form of pumping configuration in accordance with the described method.

FIGURE 2 is a schematic diagram of an enhanced form of pumping configuration in accordance with the described method.

FIGURE 3 is a side elevation view in longitudinal section of an apparatus developed for use with the described method.

FIGURE 4 is a schematic diagram of a pumping configuration involving the apparatus illustrated in **FIGURE 3**.

FIGURE 5 is a side elevation view in longitudinal section of a plurality of the apparatus illustrated in **FIGURE 3** connected in series.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

A method of downhole cyclone oil/water separation will now be described with reference to **FIGURES 1** through **5**.

Referring to **FIGURE 1**, the preferred method includes the following steps. Firstly, place a cyclone separator 12 downhole in an oil well 14 producing a mixed stream of oil, water and gas. Cyclone separator 12 includes a separation chamber 16 wherein liquids of differing densities are separated, a mixed liquids inlet 18 through which liquids pass into separation chamber 16, a first outlet 20 for liquids of a first density range to pass from separation chamber 16 and a second outlet 22 for liquids of a second density range to pass from separation chamber 16. Secondly, connect first outlet 20 to a recovery conduit 24 extending to surface (not shown). Thirdly, connect second outlet 22 to a disposal conduit 26 extending to a selected disposal site (not shown). Fourthly, connect mixed liquids inlet 18 to a pump 28 and pump a mixed stream of oil, water and gas into separation chamber 16 of cyclone separator 12. The mixed stream is separated in separation chamber 16 into a recovery stream of oil with a reduced water content which flows out of first outlet 20 and along recovery conduit 24 to the surface and a disposal stream of mainly water which flows out of second outlet 22 and along disposal conduit 26 to the selected disposal site.

Referring to **FIGURE 2**, an enhanced pumping configuration is disclosed in which a backpressure valve 30 is positioned on disposal conduit 26. The use of backpressure valve 30 ensures that there is sufficient pressure maintained to get the disposal stream into an underground disposal formation selected as a disposal site, while at the same time ensuring that the pump and cyclone separator are both operating within their most efficient operating ranges. It also enables a more accurate assessment to be made as to the amount of fluid

being pumped into the disposal site. There are other backpressure control means that can be used such as a flow restriction orifice. Backpressure valve 30 is preferred as it prevents a reversal of flow when pump 28 is turned off. In field installations which include pumps adversely affected by a reverse flow when stopped, the flow reversing the pump motor turns backward preventing the pump from being restarted. Referring to **FIGURE 2**, there is also provided a secondary pump 32 is positioned on the recovery conduit 24. Secondary pump 32 is intended to assist in conveying the recovery stream to the surface. The problem of gas breakout, previously described, does not adversely affect the operation of secondary pump 32 due to the fact that pump 28 provides sufficient pressure to maintain the majority of the gas in solution.

An apparatus for downhole cyclone separation, generally identified by reference numeral 40, been especially developed for use with the described method. When apparatus 40 is used with the described method separation capacity and production flow rates can be greatly increased. This apparatus will now be described with reference to **FIGURE 3**. Apparatus 40 includes a multiple cyclone separator housing 42 having an interior cavity 44, an mixed liquids inlet 46, a disposal stream outlet 48 and a recovery stream outlet 50. Although single inlets and outlets are illustrated, it will be appreciated that multiple inlets or outlets into housing 42 could be utilized depending upon the installation environment. A plurality of cyclone separators 12 are disposed in interior cavity 44 of multiple cyclone separator housing 42. As previously described, each of cyclone separators 12 has a separation chamber 16 wherein

liquids of differing densities are separated, a mixed liquids inlet 18 through which liquids pass into separation chamber 16, a first outlet 20 for liquids of a first density range to pass from separation chamber 16, and a second outlet 22 for liquids of a second density range to pass from separation chamber 16. Some means must be used for channelling the various flow streams flowing into mixed liquids inlet 18 and out of first outlet 20 and second outlet 22. The channelling means illustrated in **FIGURE 3** is by way of conduits 52 and 54. It should be noted that only two conduit are required as in the illustrated embodiment interior cavity 44 of multiple cyclone separator housing 42 can serve as one of the channelling means. Conduit 52 has been connected as an inlet conduit allowing liquids to pass from mixed liquids inlet 46 in multiple cyclone separator housing 42 to mixed liquids inlets 18 of each of cyclone separators 12. Conduit 54 has been connected as an outlet conduit allowing liquids to pass from first outlet 20 of each of cyclone separators 12 to recovery stream outlet 50 of multiple cyclone separator housing 42. Second outlet 22 of each of cyclone separators 12 discharges directly into interior cavity 44, so that interior cavity 44 serves to connect second outlet 22 of each of cyclone separators 12 with disposal stream outlet 48.

When apparatus 40 is used with the described method the following steps are taken, as illustrated in **FIGURE 4**. Firstly, multiple cyclone separator housing 42 is placed downhole in an oil well producing a mixed stream of oil, water and gas. Secondly, recovery stream outlet 50 of multiple cyclone separator housing 42 is connected to recovery conduit 24 extending to surface. Thirdly, disposal stream outlet 48 of multiple cyclone separator

housing 42 is connected to disposal conduit 26 extending to a selected disposal site. Fourthly, a mixed stream of oil, water and gas is pumped by means of pump 28 into mixed liquids inlet 46 of multiple cyclone separator housing 42. The mixed stream of oil, water and gas is channelled by inlet conduit 50 to mixed liquid inlets 18 of each of cyclone separators 12, whereupon the oil and water is separated in separation chamber 16 of cyclone separators 12. A recovery stream of oil with a reduced water content passes through first outlet 20 of each of cyclone separators 12 for channelling by outlet conduit 54 to recovery stream outlet 50 in multiple cyclone separator housing 42 for conveyance through recovery conduit 24 to the surface. A disposal stream of water is discharged from second outlet 22 of each of cyclone separators 12 into interior cavity 44 for channelling to disposal stream outlet 48 of multiple cyclone separator housing 42 for disposal through disposal conduit 26 to the selected disposal site.

The use of apparatus 40 provides numerous advantages. The flow rate is increased. The pressure drop across each of separators 12 is reduced, which reduces the power requirements and reduces the chance of gas breakout downstream. Multiple cyclone separators 12 provide a redundancy, if any one cyclone separator ceases to function, the remaining cyclone separators can continue to function.

A cyclone separator has a separation ratio that the percentage of the fluids flowing through first outlet 20 bears to the entire volume of fluids flowing through separation chamber 16. There is no minimum percentage. This means that in wells with an extremely high water

content, the majority of the fluids (ie. the water) can be left downhole. There is however a maximum percentage of approximately 25 percent of the total volume leaving via first outlet 20. At this maximum percentage approximately 75 percent of the fluids are leaving via second outlet 22. This creates a problem with oil wells having a low water content. There is a danger that a portion of the oil can be pumped into the disposal zone along with the water. Referring to **FIGURE 5**, in oil wells with a low water content, a plurality of apparatus 40 containing multiple cyclone separators can be connected in series. In this way a sequential reduction in the oil content can occur prior to pumping the disposal stream to the selected disposal site.

It will be apparent to one skilled in the art that modifications may be made to the illustrated embodiment without departing from the spirit and scope of the invention as defined by the Claims.

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE AS FOLLOWS:

1. A method of downhole cyclone separation including the steps of: firstly, placing a cyclone separator (12) downhole in an oil well (14) producing a mixed stream of oil, water and gas, the cyclone separator (12) including a separation chamber (16) wherein liquids of differing densities are separated, at least one mixed liquids inlet (18) through which liquids pass into the separation chamber (16), a first outlet (20) for liquids of a first density range to pass from the separation chamber (16), a second outlet (22) for liquids of a second density range to pass from the separation chamber (16); secondly, connecting the first outlet (20) to a recovery conduit (24) extending to surface; thirdly, connecting the second outlet (22) to a disposal conduit (26) extending to a selected disposal site, the method being characterized by the further step of:

fourthly, connecting the at least one mixed liquids inlet (18) to pumping means (28) and pumping a mixed stream of oil, water and gas into the separation chamber (16) of the cyclone separator (12) whereby the mixed stream is separated into a recovery stream of oil with a reduced water content which flows out of the first outlet (20) and along the recovery conduit (24) to the surface and a disposal stream of mainly water which flows out of the second outlet (22) and along the disposal conduit (26) to the selected disposal site.

2. The method of downhole cyclone separation as defined in Claim 1, wherein backpressure control means (30) are positioned on one of the second outlet (22) and the disposal conduit (26).

3. The method of downhole cyclone separation as defined in Claim 1, wherein secondary pump means (32) is connected to the recovery conduit (24) whereby the recovery stream is pumped to the surface.

4. The method of downhole cyclone separation as defined in Claim 1, wherein a plurality of cyclone separators (12) are enclosed within a multiple cyclone separator housing (42).

5. The method of downhole cyclone separation as defined in Claim 4, wherein the multiple cyclone separator housing (42) has a mixed liquids inlet (46), a disposal stream outlet (48) and a recovery stream outlet (50), mixed liquids inlet (46) being connected by a conduit (52) to the mixed liquids inlets (18) of each of the cyclone separators (12), a recovery stream outlet (50) being connected by a conduit (54) to the first outlet 20 of each of the cyclone separators (12), and second outlet (22) of each of cyclone separators (12) discharging directly into an interior cavity (44) of multiple cyclone separator housing (42) and passing out of interior cavity via disposal stream outlet (48).

6. The method of downhole cyclone separation as defined in Claim 4, wherein a plurality of multiple cyclone separator housings (42) are connected in series thereby effecting a sequential reduction in the oil content in the disposal stream.

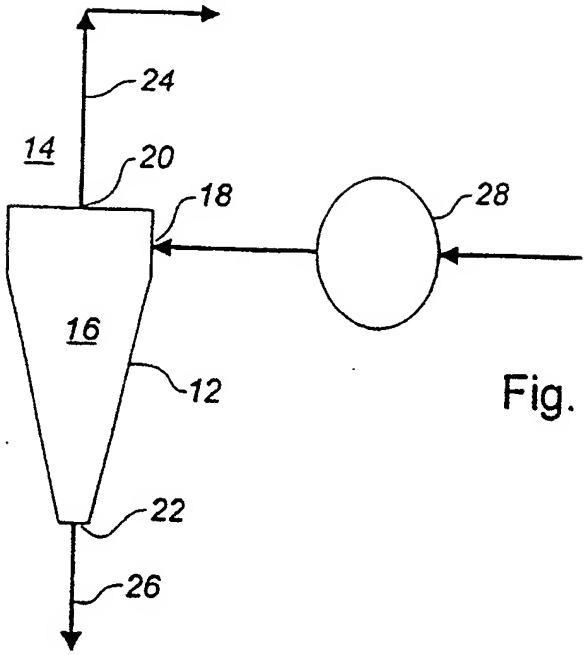

Fig. 1.

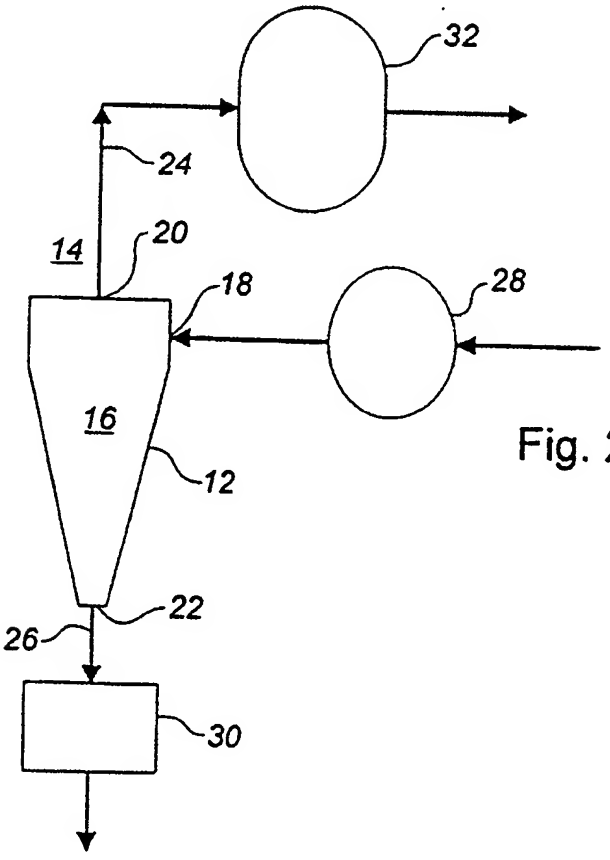

Fig. 2.

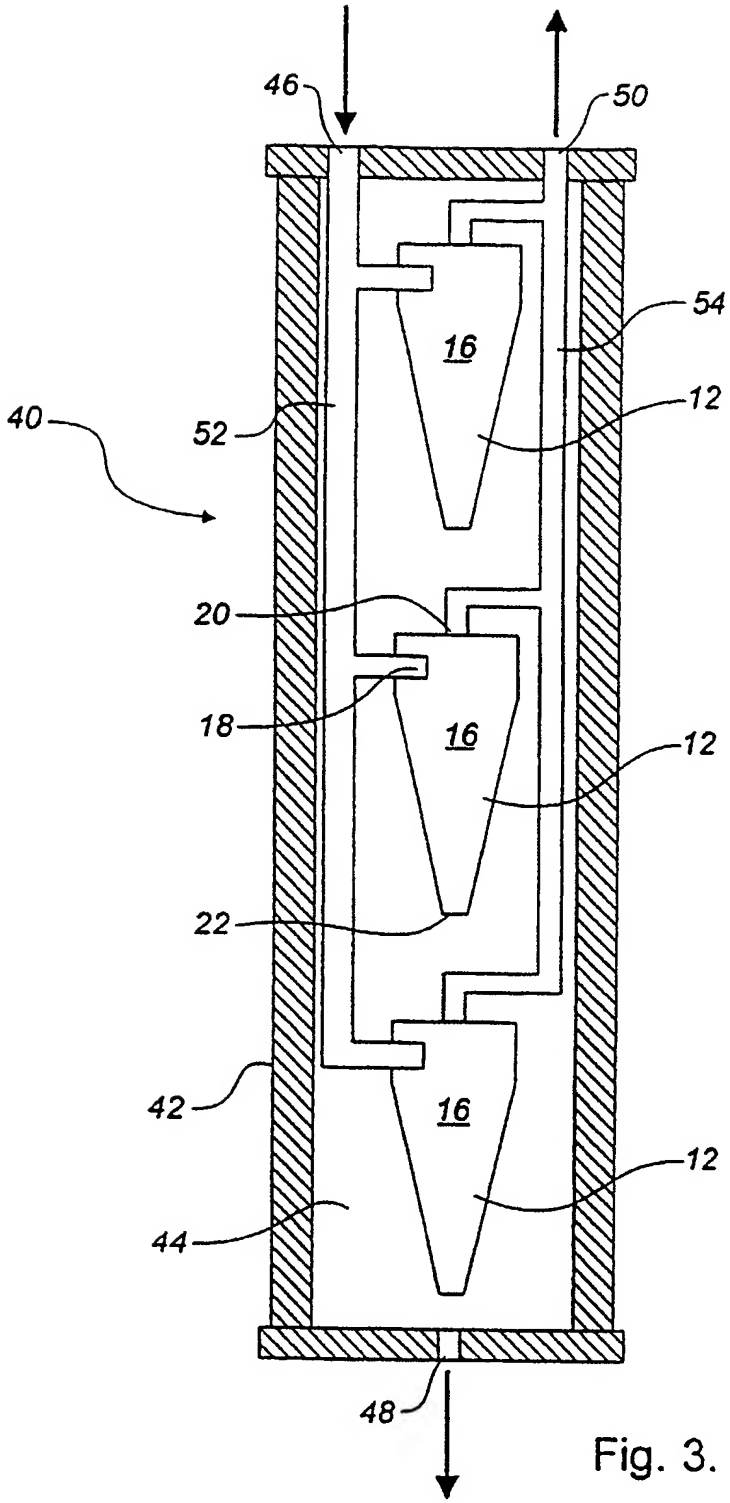

Fig. 3.

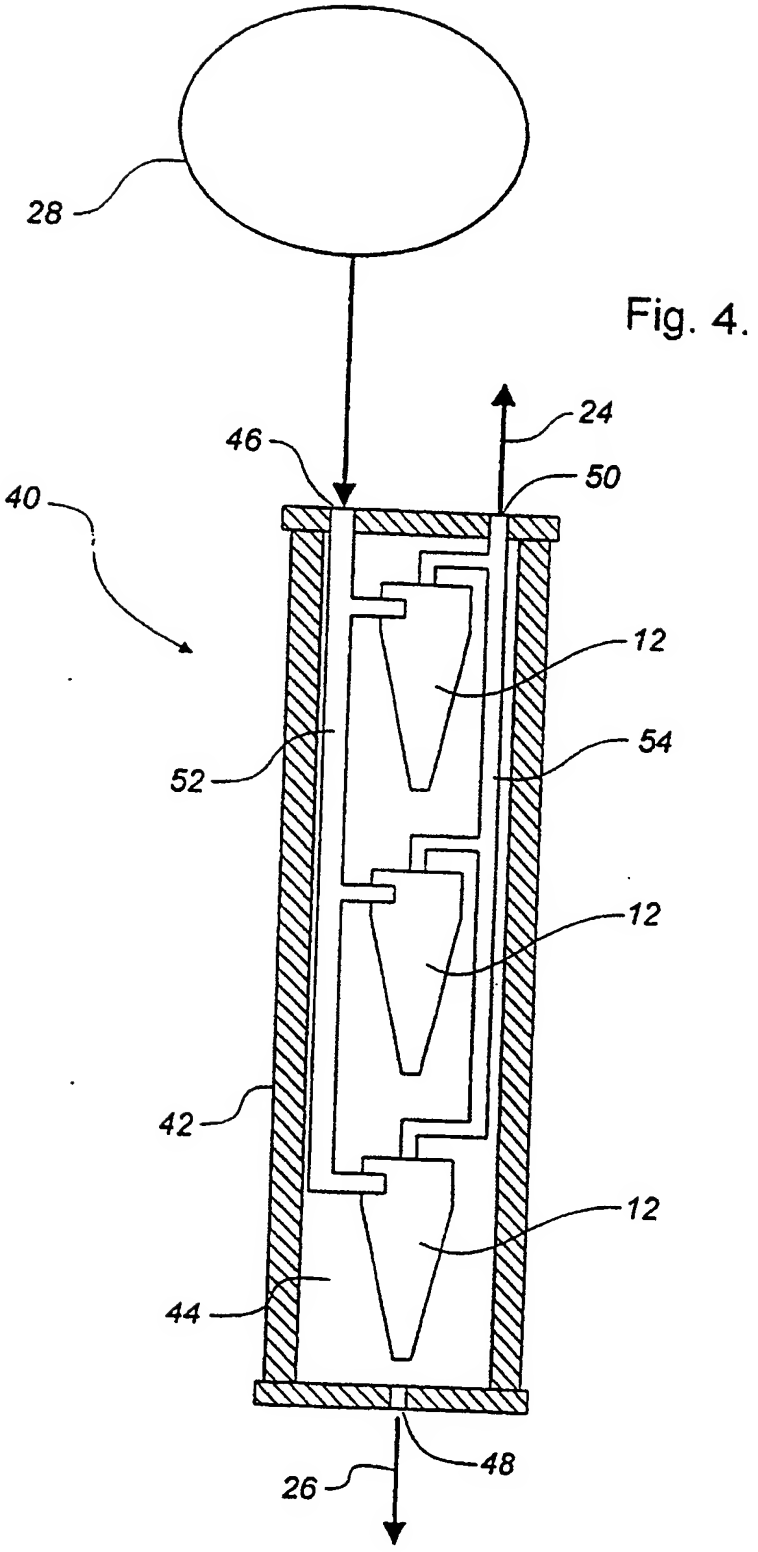

Fig. 4.

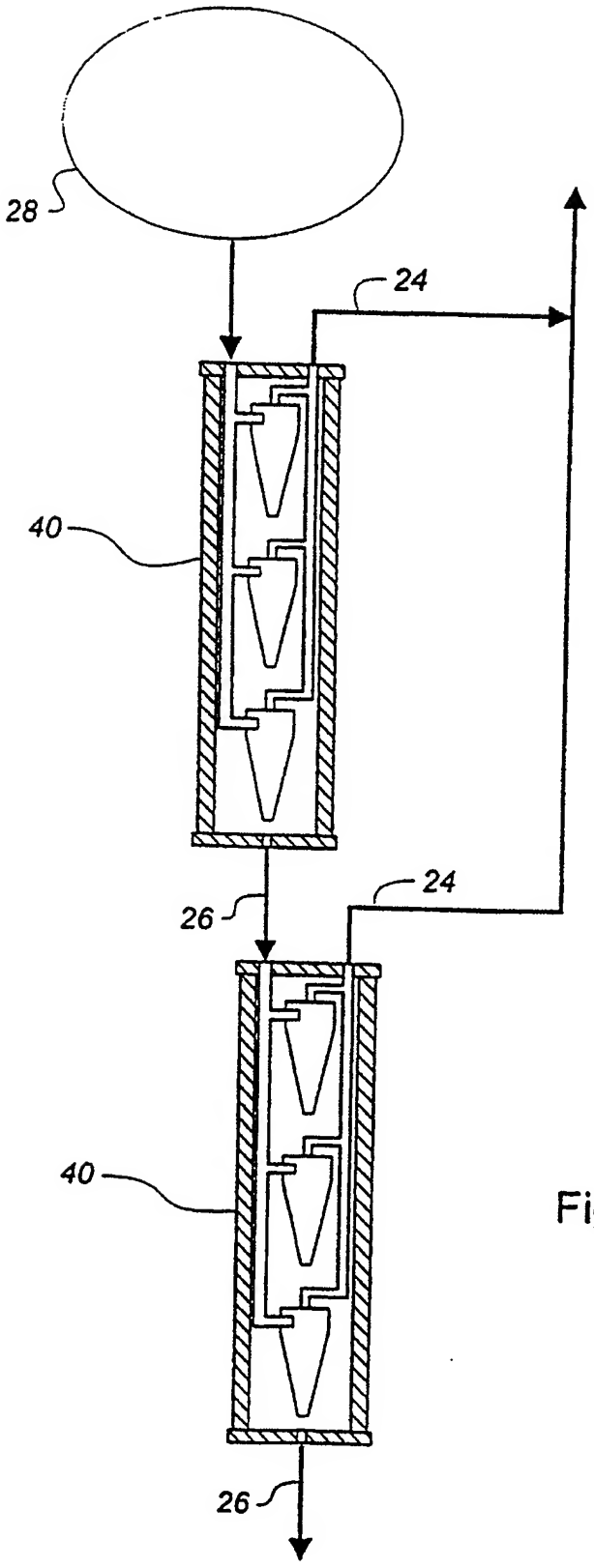

Fig. 5

INTERNATIONAL SEARCH REPORT

Inter nal Application No
PCT/CA 95/00549

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 E21B43/38

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 E21B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US,A,5 296 153 (B.C.PEACHEY) 22 March 1994 cited in the application see the whole document	1
A	WO,A,94 13930 (READ PROCESS ENGINEERING) 23 June 1994 cited in the application see the whole document	1,4-6
A	WO,A,95 09970 (ANIL A/S) 13 April 1995 see the whole document	1
A	EP,A,0 420 751 (ELF AQUITAINE) 3 April 1991 see abstract; figures	1

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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Information on patent family members

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